

1 Soil Conductivity as a Measure of Soil and Crop Status – A Four Year Summary

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Introduction

Sustainable agriculture requires innovative and practical tools to optimize farm economics, conserve soil organic matter, and minimize negative environmental impacts. Waste management research has been successful in characterizing the nutrient content of manures, the movement of the nutrients in various soil types and transformations that occur with time. A pervasive issue remains regarding the location of nutrients and the dynamic transformations that occur at the field level. Soil conductivity data shows promise to address these issues. Soil conductivity data can be collected using noninvasive techniques in conjunction with GPS positioning to record field locations of high conductivity as well as monitoring dynamic changes throughout a crop growing season. Electrical conductivity has generally been associated with determining soil salinity; however, EC also can serve as a measure of soluble nutrients for both cations and anions, and is useful in monitoring the mineralization of organic matter in soil. The utility of EMI methods were studied to evaluate the agronomic effectiveness and environmental consequences of nitrogen fertilization for varying rates of compost, manure, and commercial fertilizer with and without the use of cover crops.

Procedure

A center-pivot irrigated field (research plot is approximately 15 acres) of silage corn located at the U. S. Meat Animal Research Center, Clay Center, Nebraska (USMARC) served as a comparison site for various manure and compost application rates for replacement of commercial fertilizer, with the same treatment assigned to field plots for ten consecutive years. The soil series at this site is a Crete silt loam, 0-1% slope.

The replicated study had a main treatment (Fig. 1) of cover crop using winter wheat that was no-till drilled following silage harvest then incorporated into the soil the following spring. The field also had sub-treatments (Fig. 1) of manure and commercial fertilizer applied at the nitrogen requirement of the corn silage crop.

The treatments were monitored using instruments that estimate soil conductivity based on amplitude of a soil-coupled low frequency electromagnetic signal. This measurement was combined with GPS position data to form conductivity maps. The field was surveyed approximately weekly during the growing season resulting in about 29 conductivity maps per season; soil cores were taken at the time of the surveys to provide direct measurements of the soil nutrients. Soil temperatures were recorded and used to compensate for the temperature sensitivity of the soil conductivity meters.

Results

A representative soil conductivity image of the cornfield is shown in Fig. 2. When the series of images for a growing season are viewed in sequence, the maps illustrate field dynamics with overall soil conductivity values rising uniformly with time (images not shown) early in the season. The treatments associated with manure and compost for the no-cover main treatments were distinguished by light stripes (higher soil conductivity values) on the map. The cover crop consistently results in a darker (lower conductivity) region for this portion of the season due to higher nutrient uptake of the cover crop. Subsequent darkening of the overall image occurs in later maps as crop uptake and nutrient transport dominate the image. The image dynamics are more evident in the mean values extracted from the survey data and illustrated in Fig. 3. These values represent averages for each treatment (approximately 80 readings) across replicates for the no-cover crop treatments for 2002.

Three primary dynamic quantities in a cornfield are the soil temperature, soil moisture, and nutrient levels. The soil conductivity data for 2000-2003 have been corrected (Fig. 3) to the equivalent temperature of 25°C. The remaining dynamics of soil moisture and nutrient levels ($\text{NO}_3\text{-N}$ being a primary contributor) were examined using a statistical procedure designated as the standardized estimate. This approach partitions the percent contribution between the differences in values of soil moisture and differences in values of $\text{NO}_3\text{-N}$ toward the differences of soil conductivity, across survey dates; this test was done for temperature corrected soil conductivity data for 2000-2003 (each year was analyzed independently). Profile weighted soil conductivity differences of no-cover crop compared to a cover crop accounted for 79, 98, 93, and 98% of the variability due to $\text{NO}_3\text{-N}$ differences for years 2000, 2001, 2002, and 2003, respectively, indicating that the primary contributor to the differences between the cover crop and no cover crop soil conductivity values over the growing seasons was nitrate level differences.

Plot treatment means distinctive shapes (Fig. 3) can be interpreted from the perspective of $\text{NO}_3\text{-N}$ as responsible for key features. Every plot begins with manure/compost being applied early, followed by a soil conductivity value that gradually increases as the season progresses. Planting dates varied from day-of-year 114 to 137, and did not have an immediate impact on soil conductivity. The crop produces a visible change in soil conductivity approximately 50 days after planting, as the crop achieves about 30 cm height; 30 cm is a stage of increasing $\text{NO}_3\text{-N}$ uptake. The apparent conductivity makes a noticeable downturn that lasts until about the time the corn silks. The downturn in soil conductivity corresponds to the time of maximum nutrient uptake; a time when $\text{NO}_3\text{-N}$ was rapidly being removed from the soil. Between the silk stage and harvest the soil conductivity curve levels out; then soil conductivity begins a gradual increase as a response to mineralization, until the end of the season.

Implications

Four years of soil conductivity surveys established response patterns of a silage cornfield for the organic and inorganic treatments under cover and no-cover conditions; the patterns, for

the most part, are explainable by organic N transformation to inorganic N with associated crop uptake. Comparing the cover crop effects on soil conductivity over the four year period revealed low soil conductivity values for cover crop at the beginning and ending of the growing season; both the cover crop and no cover crop trended toward convergence at the time of increasing $\text{NO}_3\text{-N}$ uptake. This four-year study supports the initial findings of a 1999 study that soil conductivity appears to be a reliable indicator of soluble N gains and losses in the soil under study, and may serve as a measure of available N sufficiency for corn early in the growing season, as well as an indicator of $\text{NO}_3\text{-N}$ surplus after harvest when soluble N is prone to loss from leaching and/or runoff.

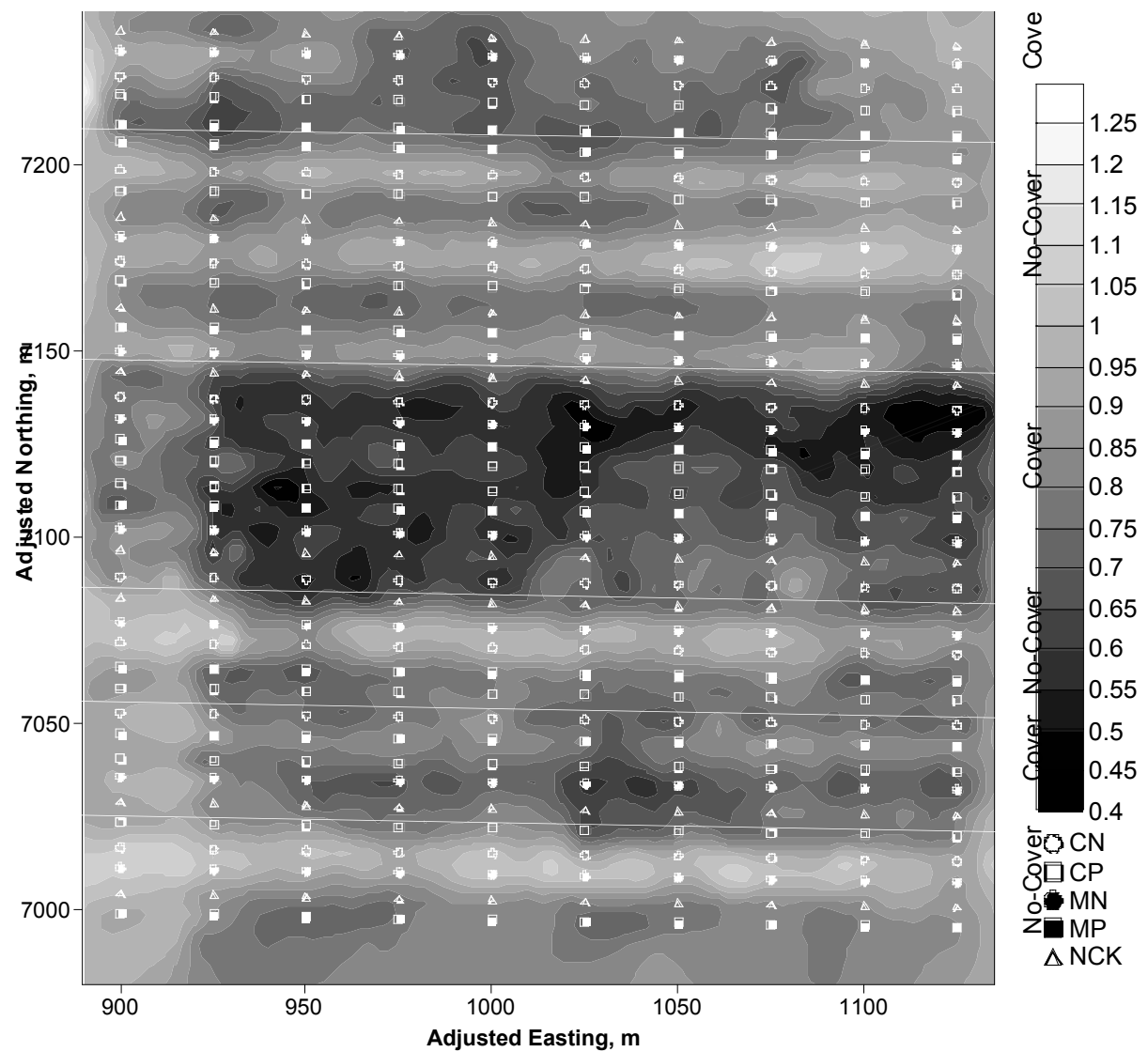


Figure 1. Split plot design with four replicates of main plot (cover and no-cover) and sub-plots (manure and compost applied at either the N or P needs of the silage corn crop, as well as commercial fertilizer). Soil cores were taken in replicate 2 (□). Treatments are designated: manure @ crop requirement N rate (MN), compost @ crop requirement N rate (CN), manure at crop requirement P rate (MP), compost @ crop requirement P rate (CP), and a commercial fertilizer check (NCK); winter wheat cover (+CC) and no-cover (-CC).

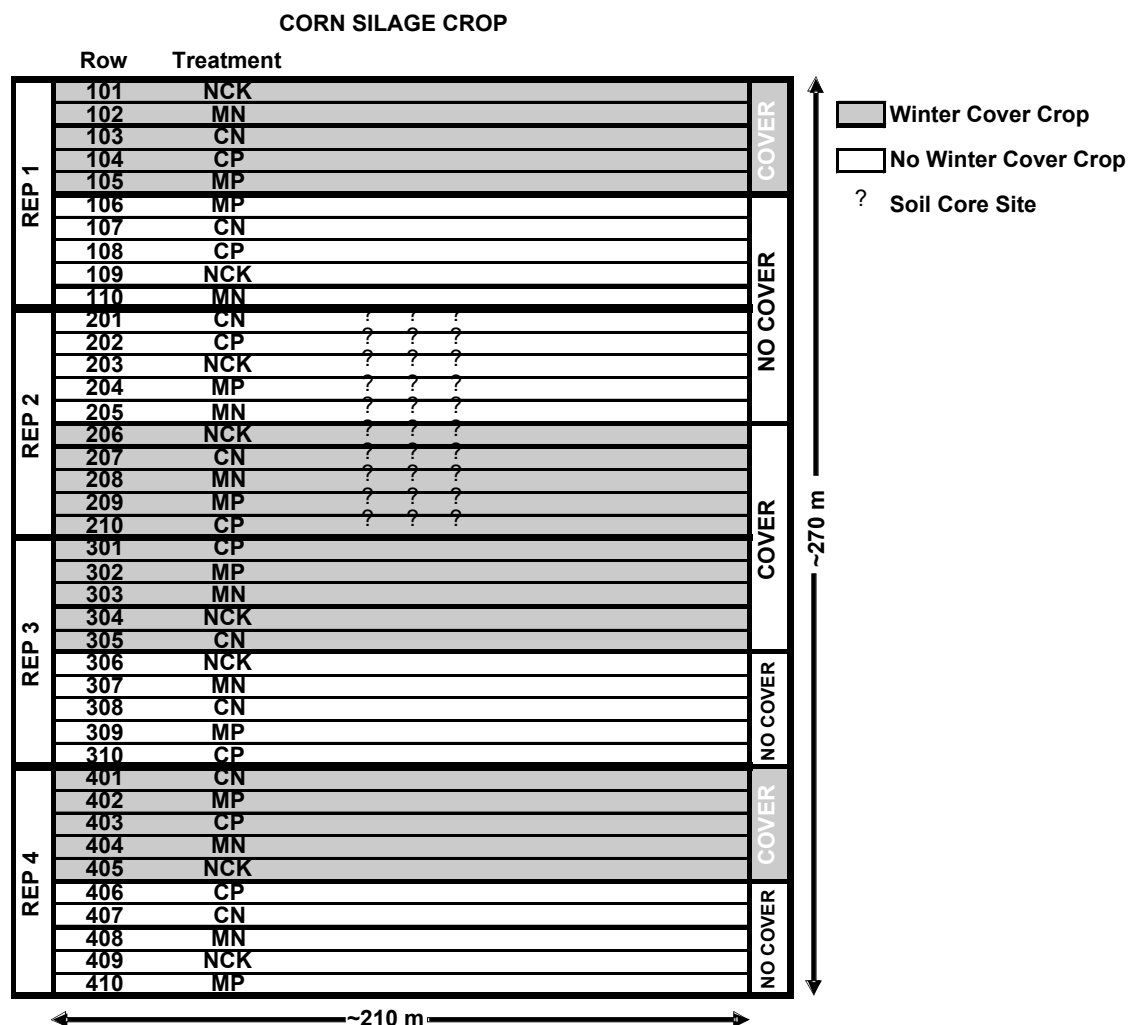


Figure 2. Representative apparent soil conductivity (soil conductivity) map as generated on June 17, 2002. Soil conductivity map is overlaid with treatment symbols.

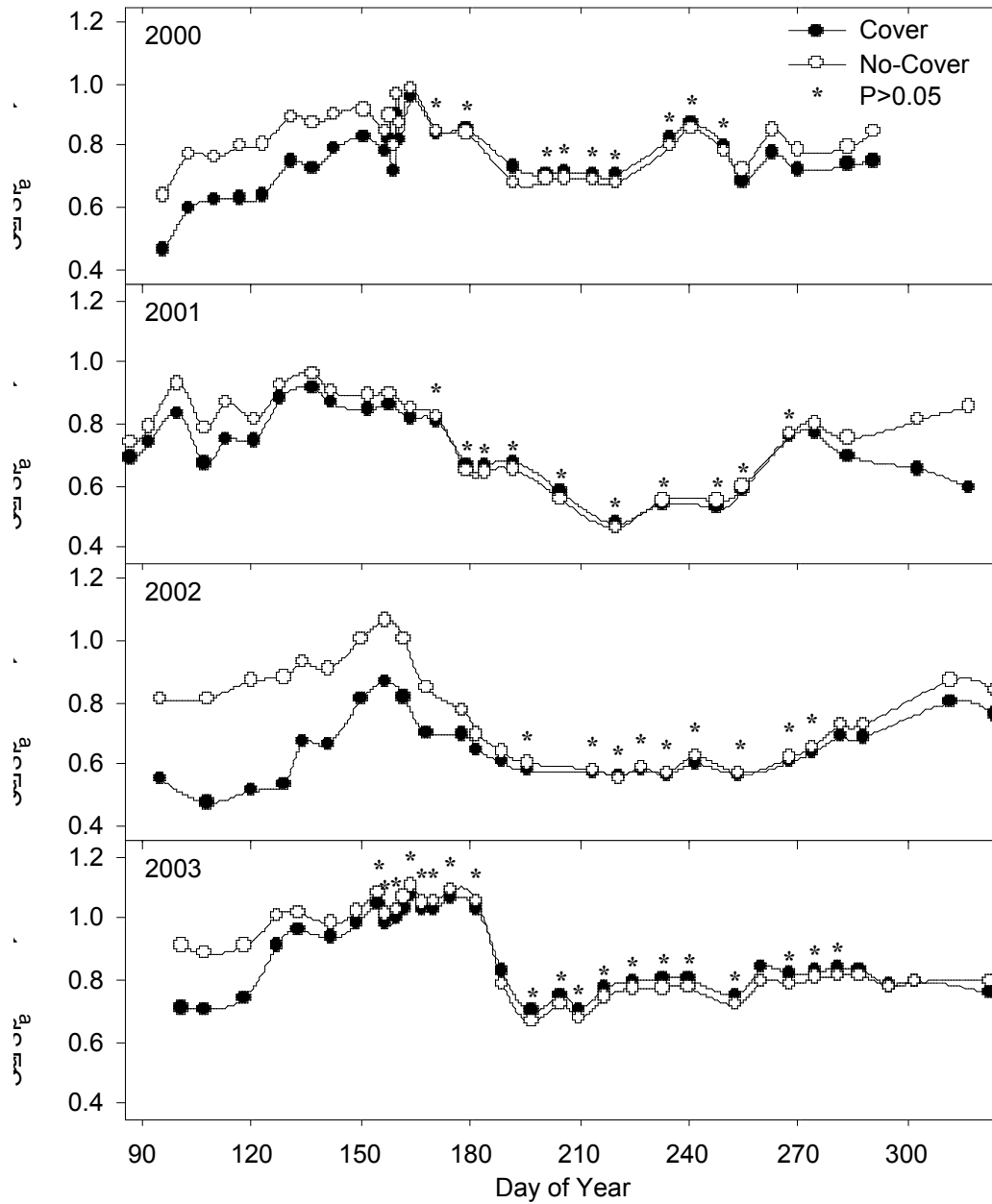


Figure 3. Figure 8. Apparent electrical conductivity for the main treatment of winter wheat cover and no-cover during 2000, 2001, 2002, and 2003. Asterisks indicate survey dates when the mean values of cover and no-cover were not significantly different ($P > 0.05$).